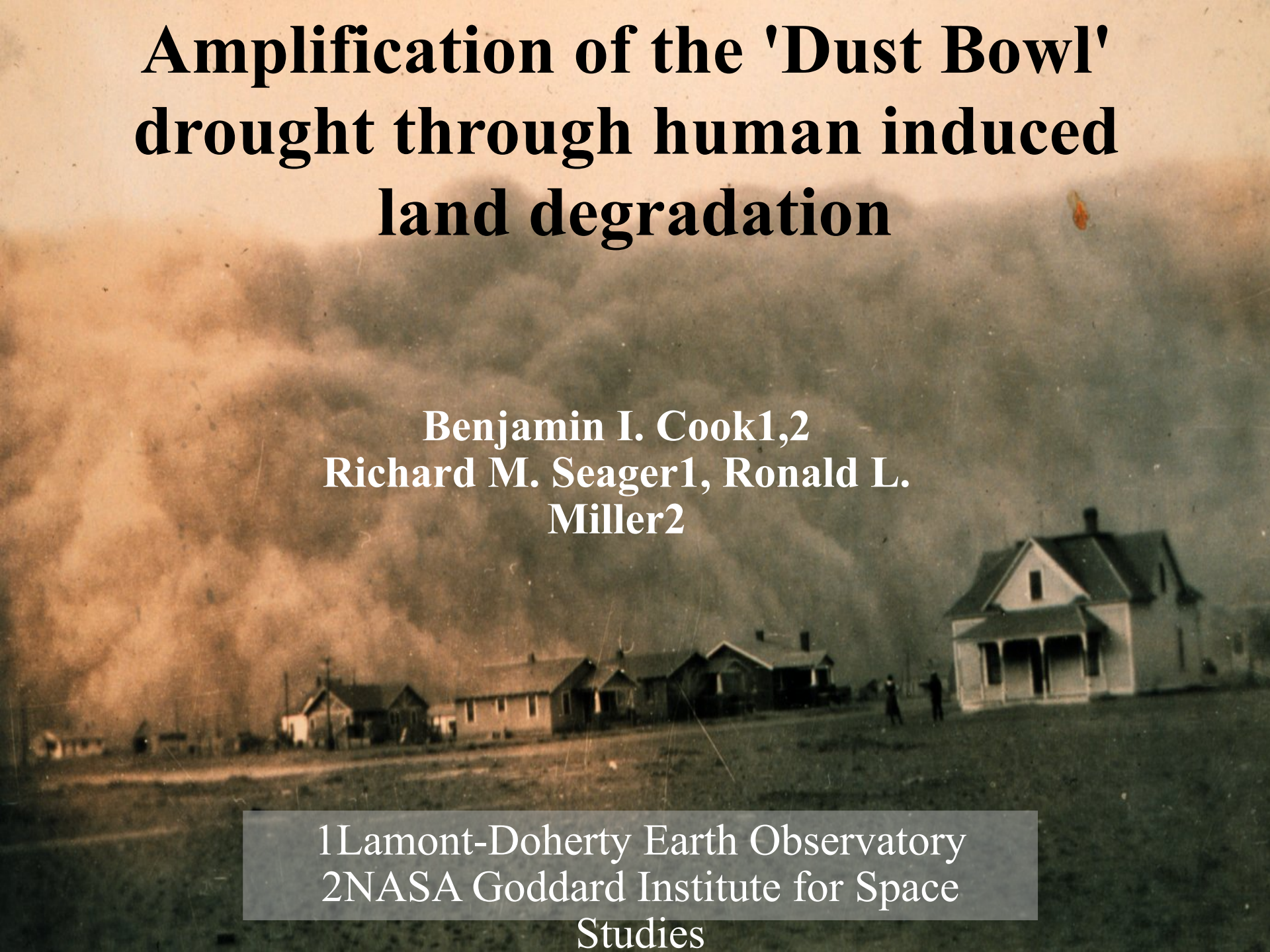
Amplification of the 'Dust Bowl' drought through human induced land degradation



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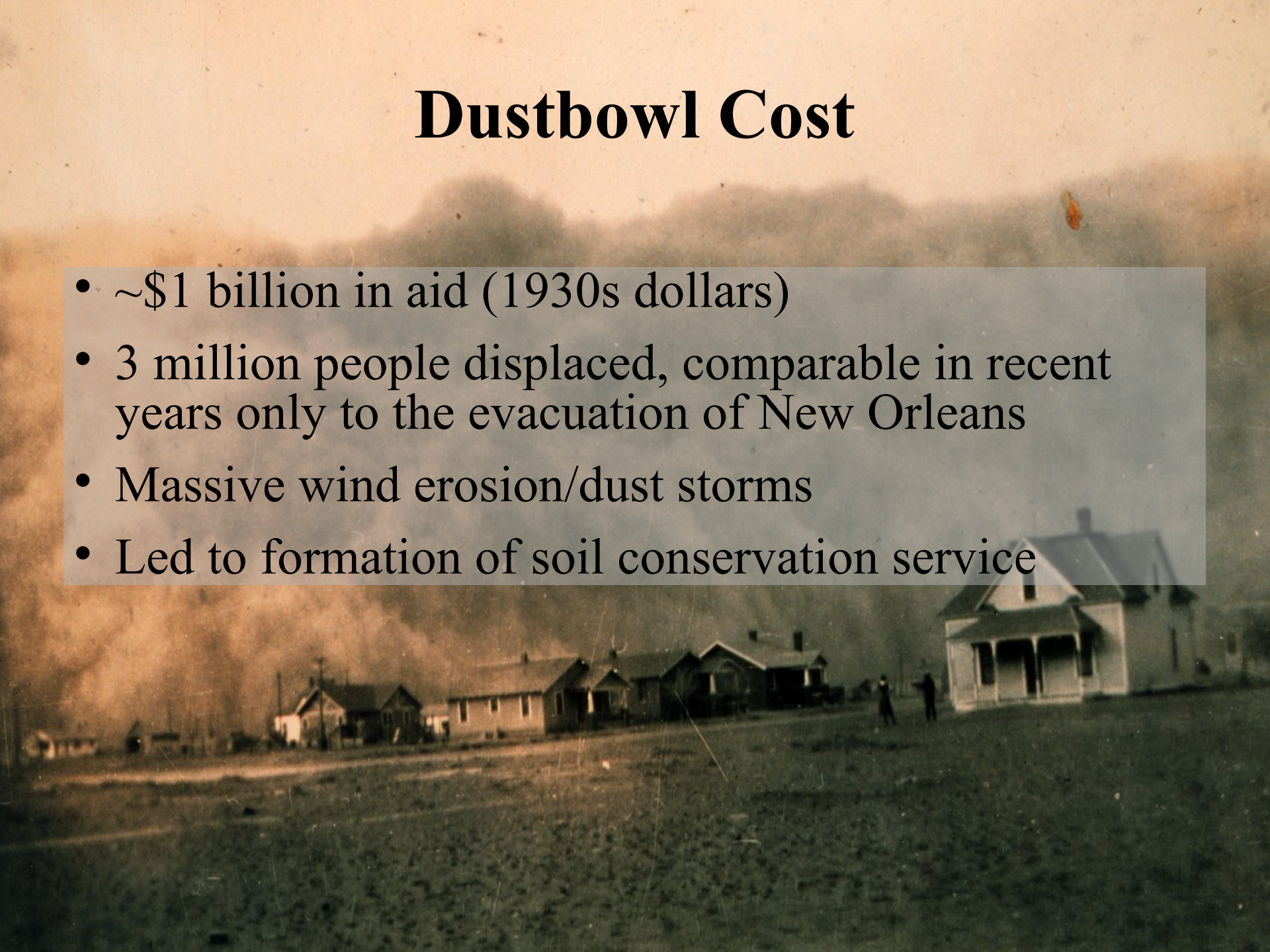
1Lamont-Doherty Earth Observatory
2NASA Goddard Institute for Space Studies

Dustbowl Cost

- ~$1 billion in aid (1930s dollars)
- 3 million people displaced, comparable in recent years only to the evacuation of New Orleans
- Massive wind erosion/dust storms
- Led to formation of soil conservation service



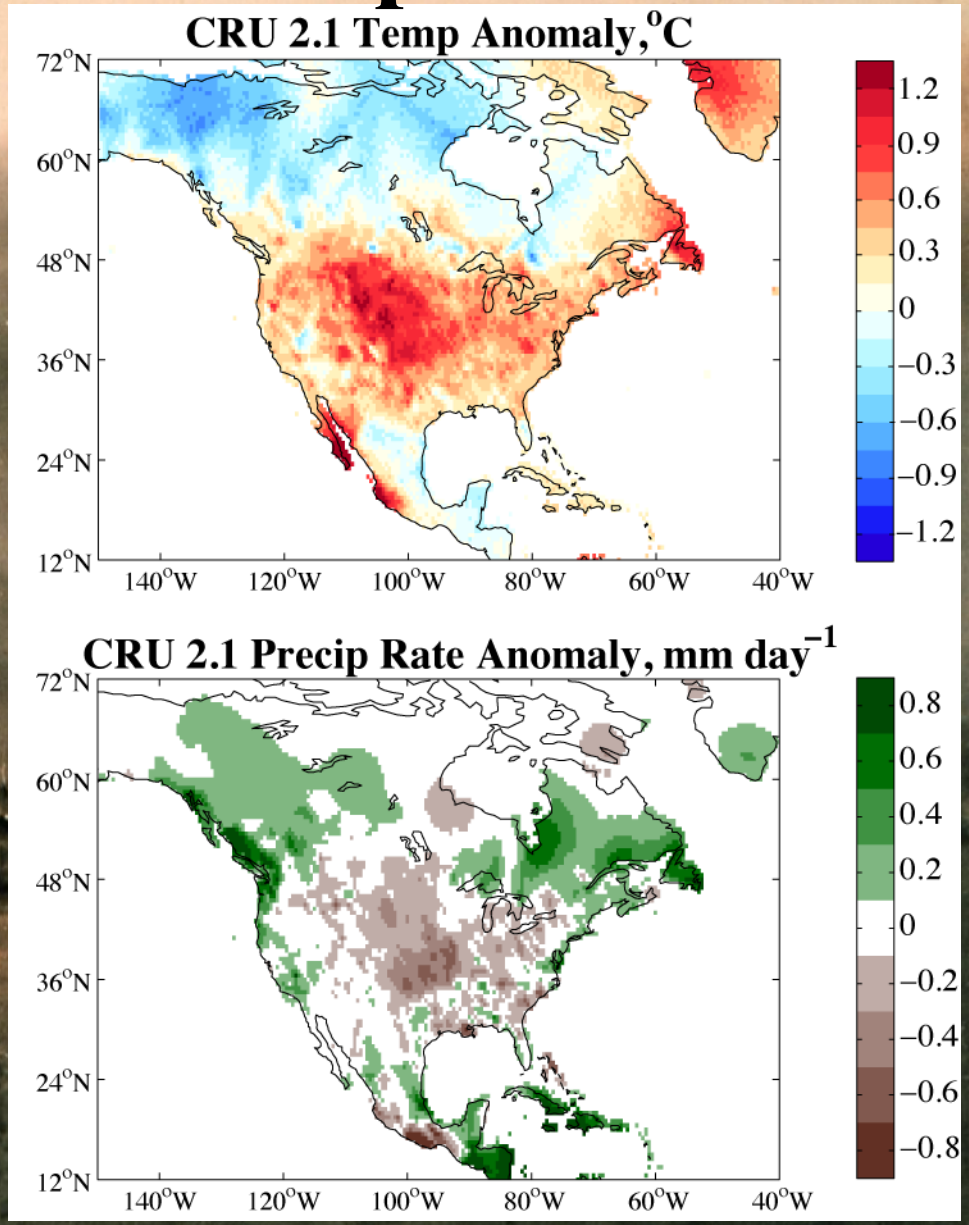
source: http://www.weru.ksu.edu/new_weru/multimedia/dustbowl/dustbowlpics.html

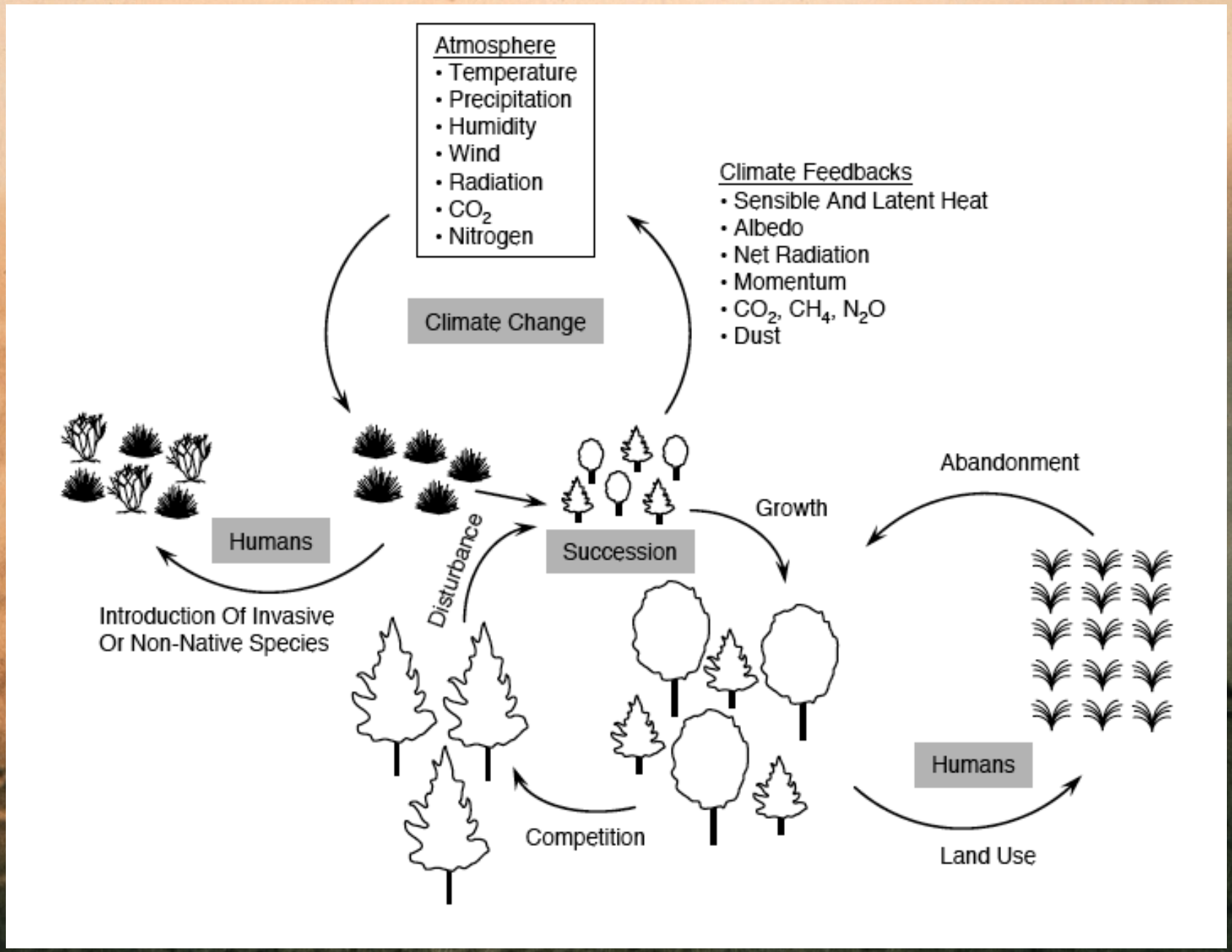
Crop Failure

source: http://www.heartlandmicrobes.com/Wheat_Pictures_018_op_800x533.jpg
source: http://farm1.static.flickr.com/63/198233348_46823058f8.jpg?v=0

The 'Dust Bowl': Temperature and Precipitation

- Initiated by cold SSTs in the eastern tropical Pacific ('La Nina')
- Much different spatial pattern than typical 'La Nina' drought
- Precip anomaly centered over Great Plains
- High temperatures across US
- Role of the land surface?



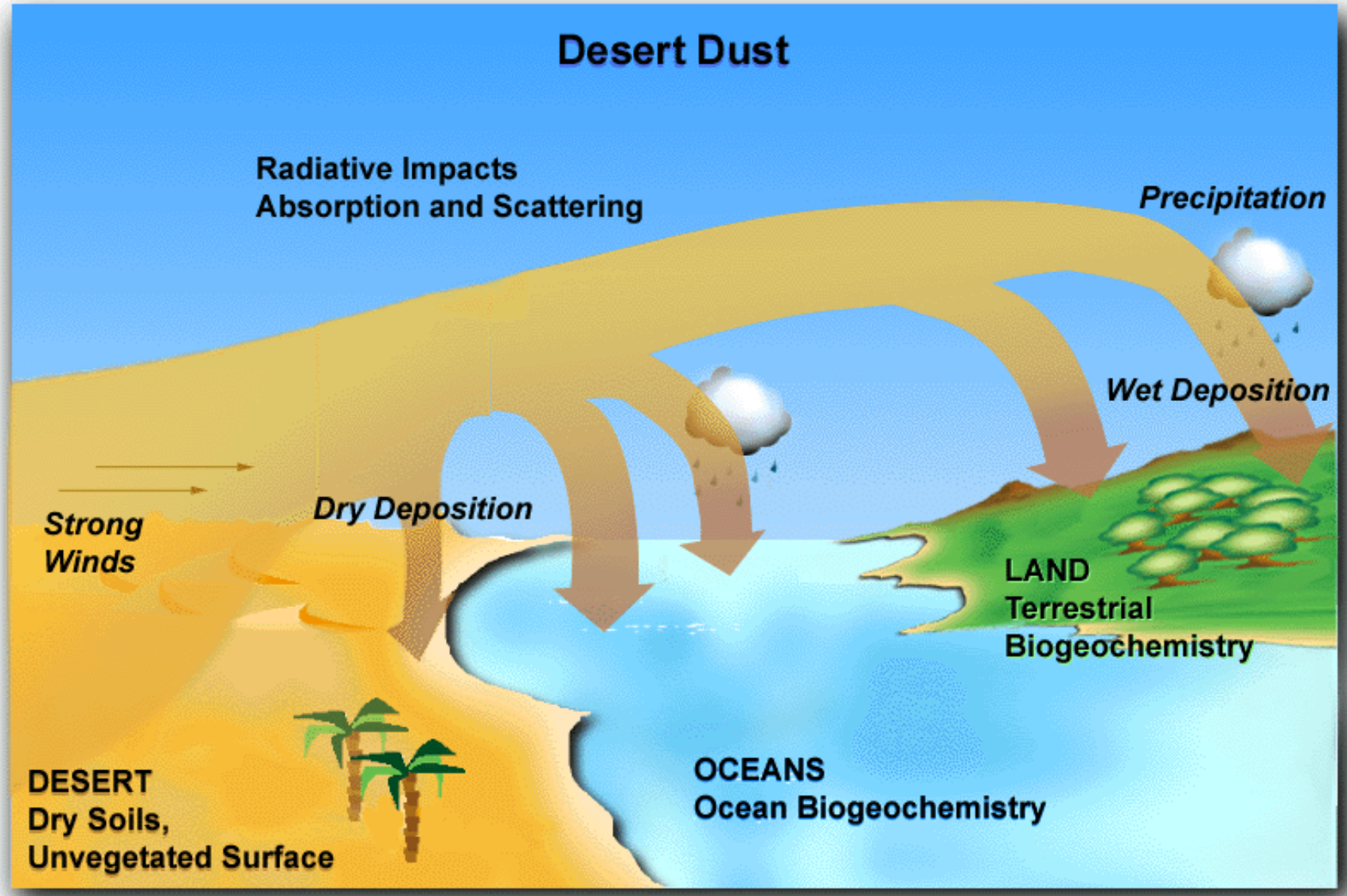


source: Bonan (2002), *Ecological Climatology*

Vegetation Feedbacks

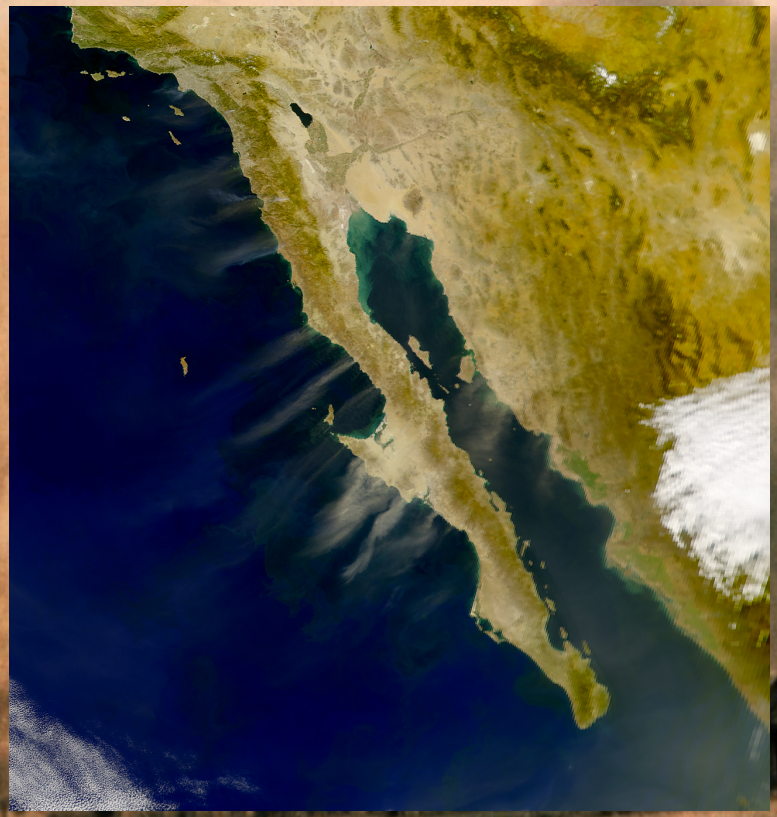
http://graphics8.nytimes.com/images/2007/08/14/science/fence_600.2.jpg
http://164.100.52.111/images/pictures/Shola%20vegetation%20-%20Nilgiris.JPG

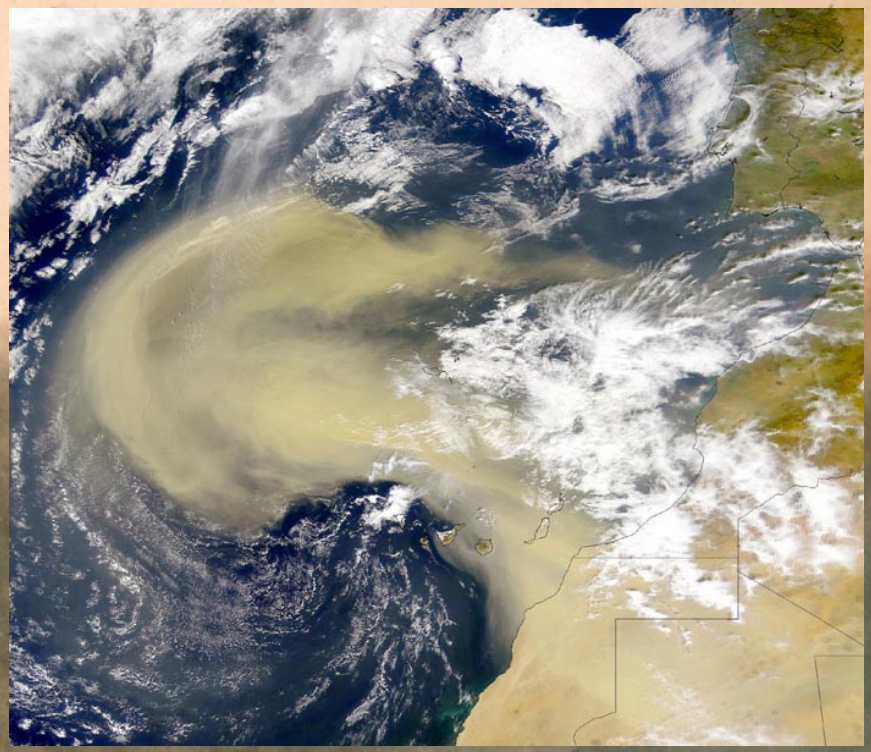
Dust Aerosols (I)

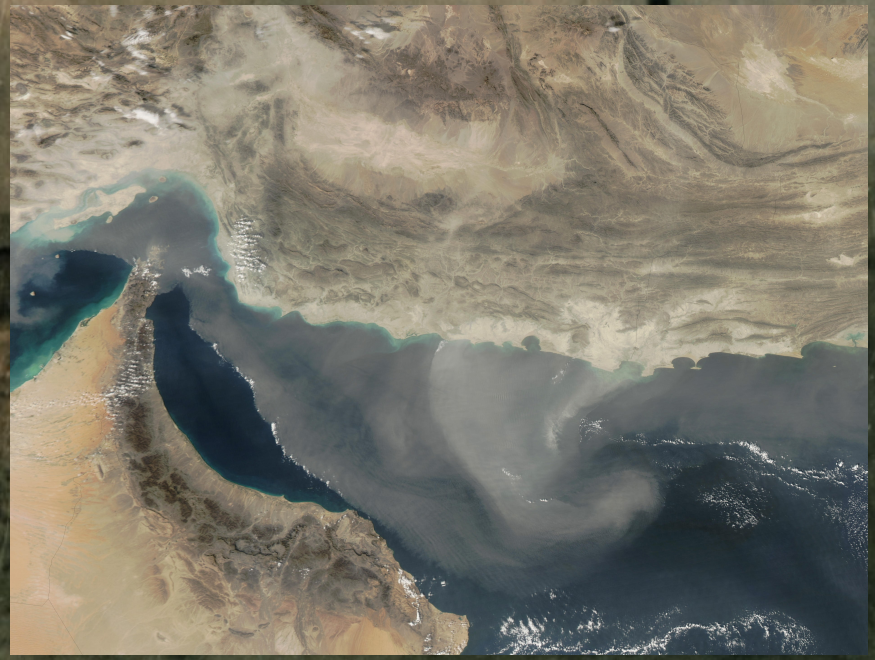


source: http://www.geo.cornell.edu/eas/PeoplePlaces/Faculty/mahowald/dust.gif

Dust Aerosols (II)







source: SeaWiFS/MODIS, NASA GSFC

Long term Dust Sources

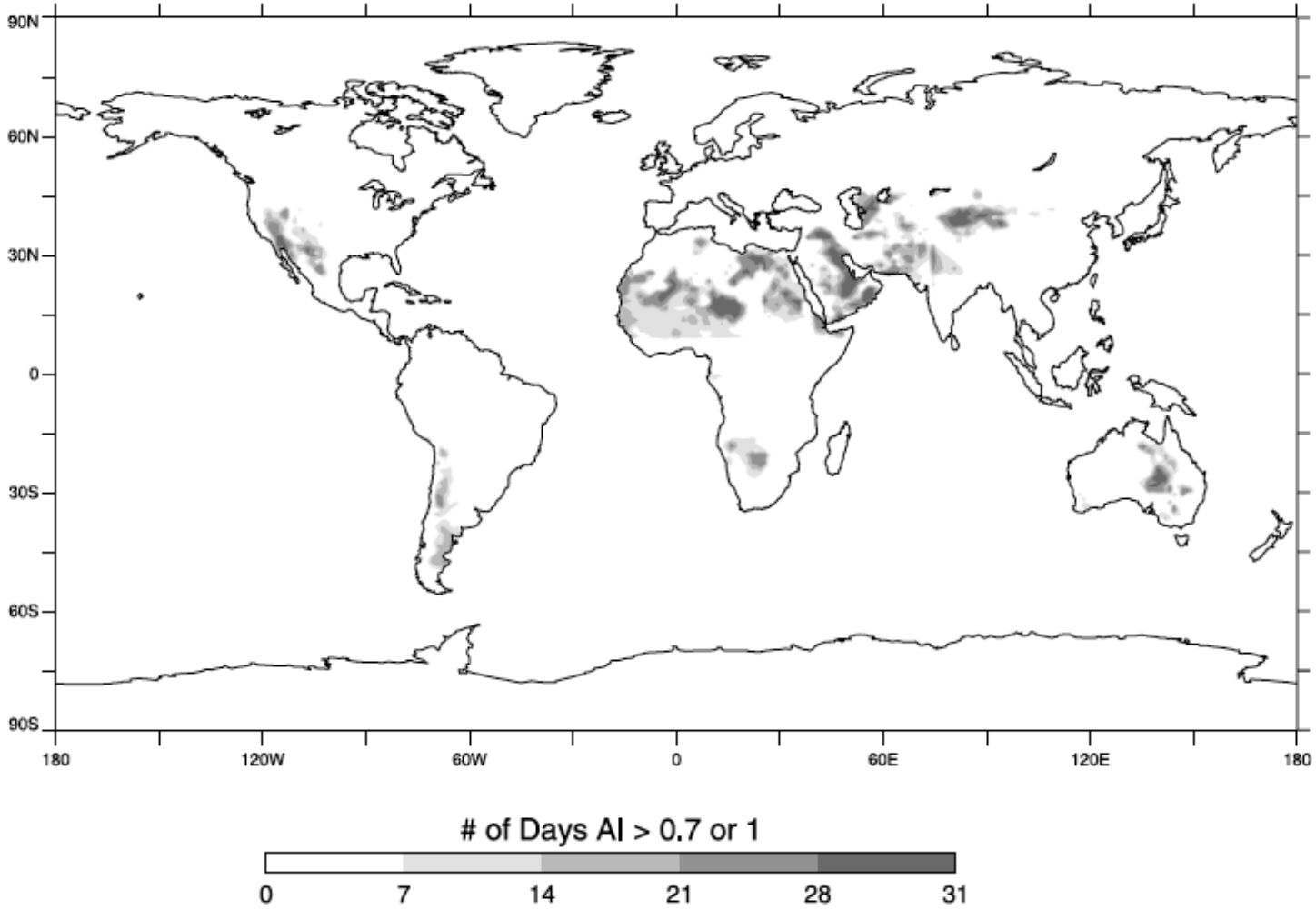


Figure 4. The global distribution of TOMS dust sources. Figure 4 is a composite of selected monthly mean TOMS AAI frequency of occurrence distributions for specific regions using those months which best illustrate the configuration of specific dust sources. The distributions were computed using a threshold of 1.0 in the dust belt and 0.7 everywhere else.

source: Prospero et al, 2002

GISS ModelE

- State of the art atmospheric general circulation model
- F40 Horizontal Resolution (~2^{o}x2.5^{o})
- Includes integrated dust model (radiatively active)
- SST/CROP/Dust runs forced by observed sea surface temperatures (1932-1939)
- Five member ensemble, with each ensemble member starting from a different initial condition
- Run on 32 processors; ~1.10 minutes for each model day

Dust Modeling

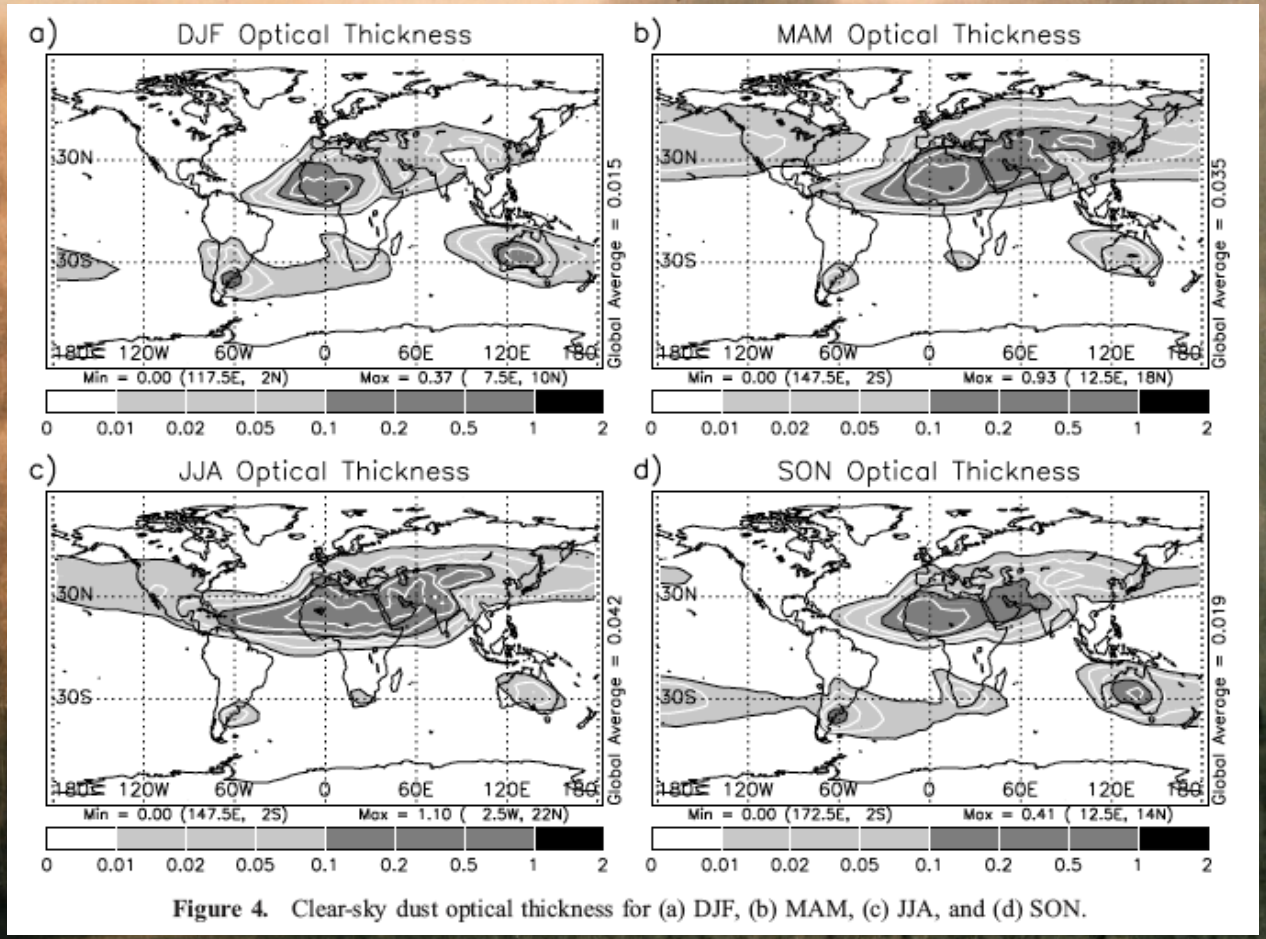
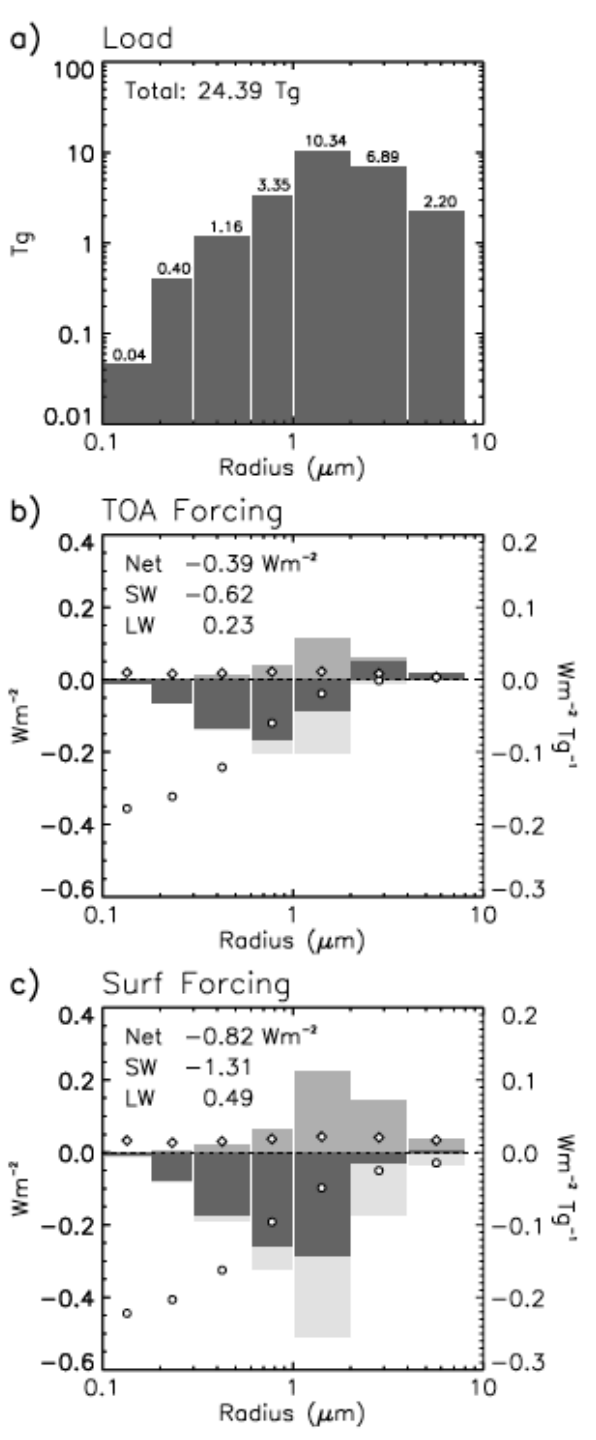


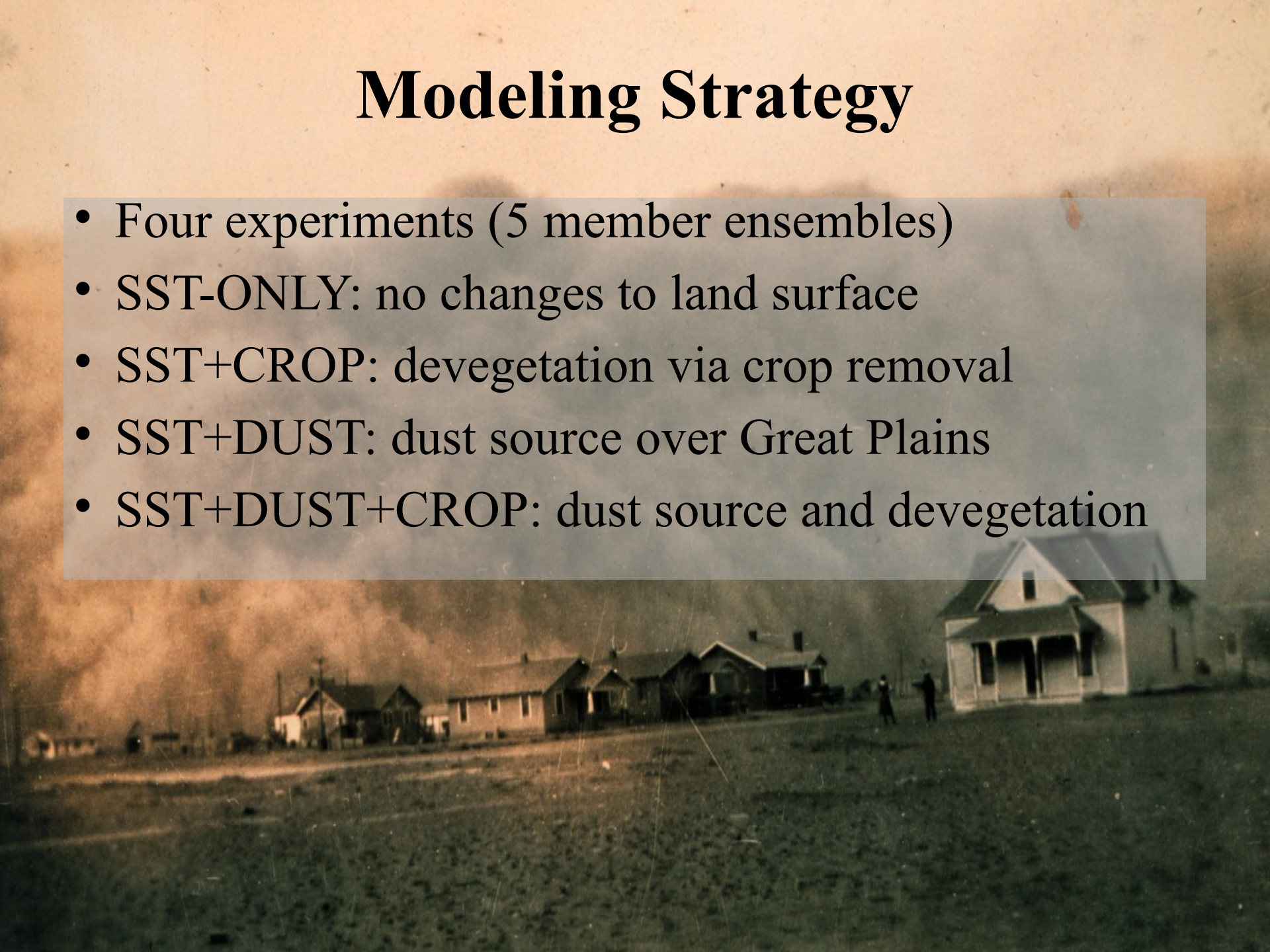
Figure 4. Clear-sky dust optical thickness for (a) DJF, (b) MAM, (c) JJA, and (d) SON.



source: Miller et al, 2006

Modeling Strategy

- Four experiments (5 member ensembles)
- SST-ONLY: no changes to land surface
- SST+CROP: devegetation via crop removal
- SST+DUST: dust source over Great Plains
- SST+DUST+CROP: dust source and devegetation



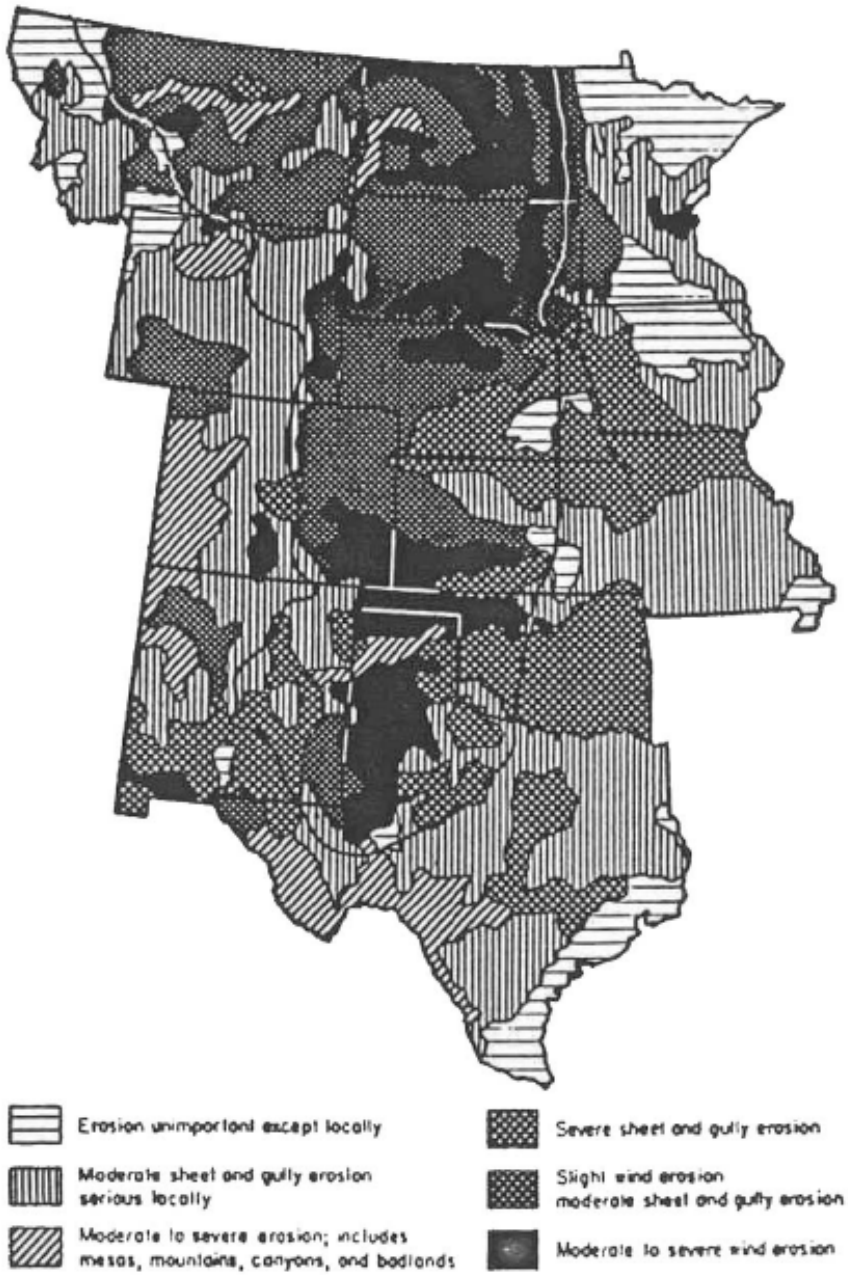
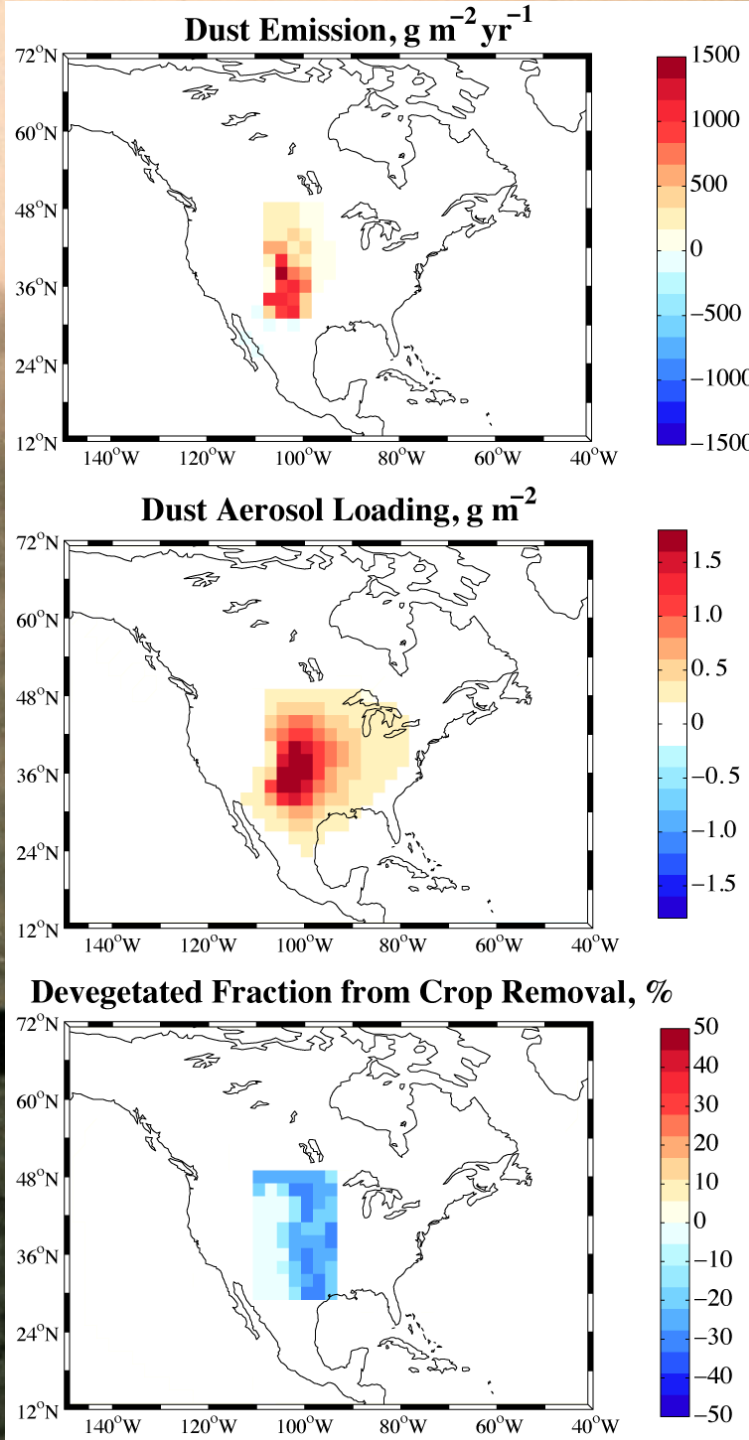
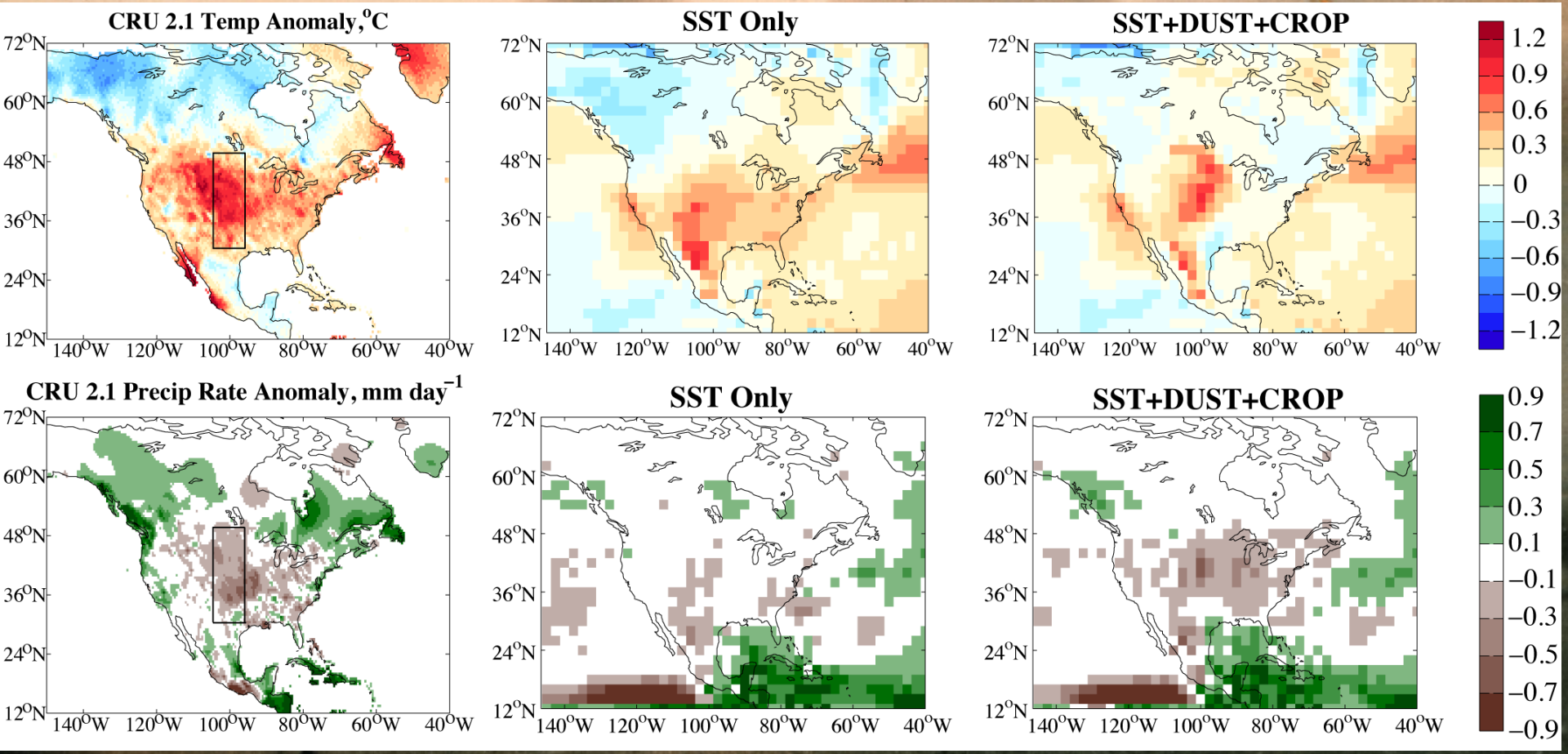


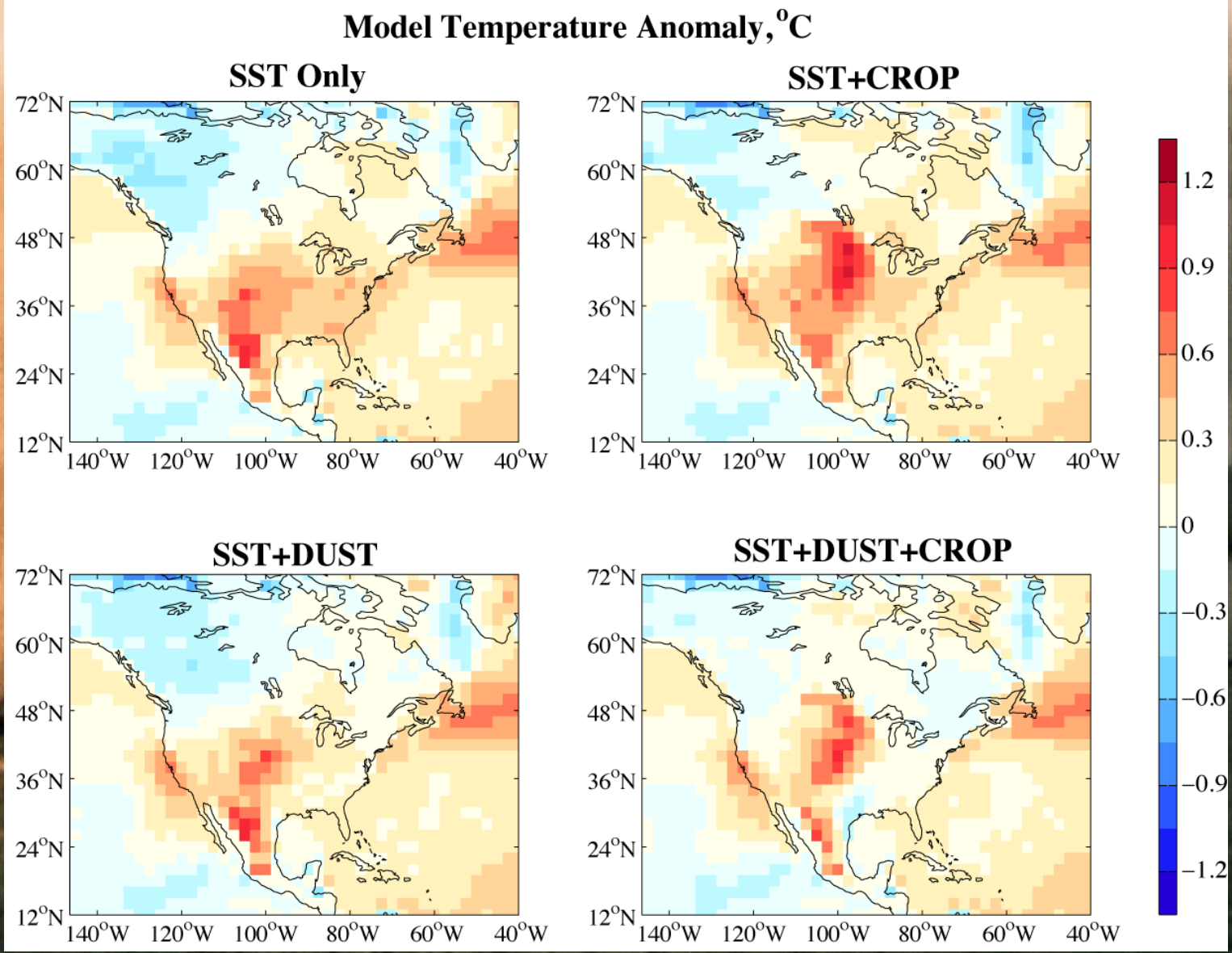
FIG. 1.—Wind erosion in the Great Plains in the 1930s. An irregular line bounds the Great Plains region as delimited by the Great Plains Committee. Source: Adapted from "General Distribution of Erosion" (U.S. Dept. Agriculture, Soil Conservation Service, August 1936).



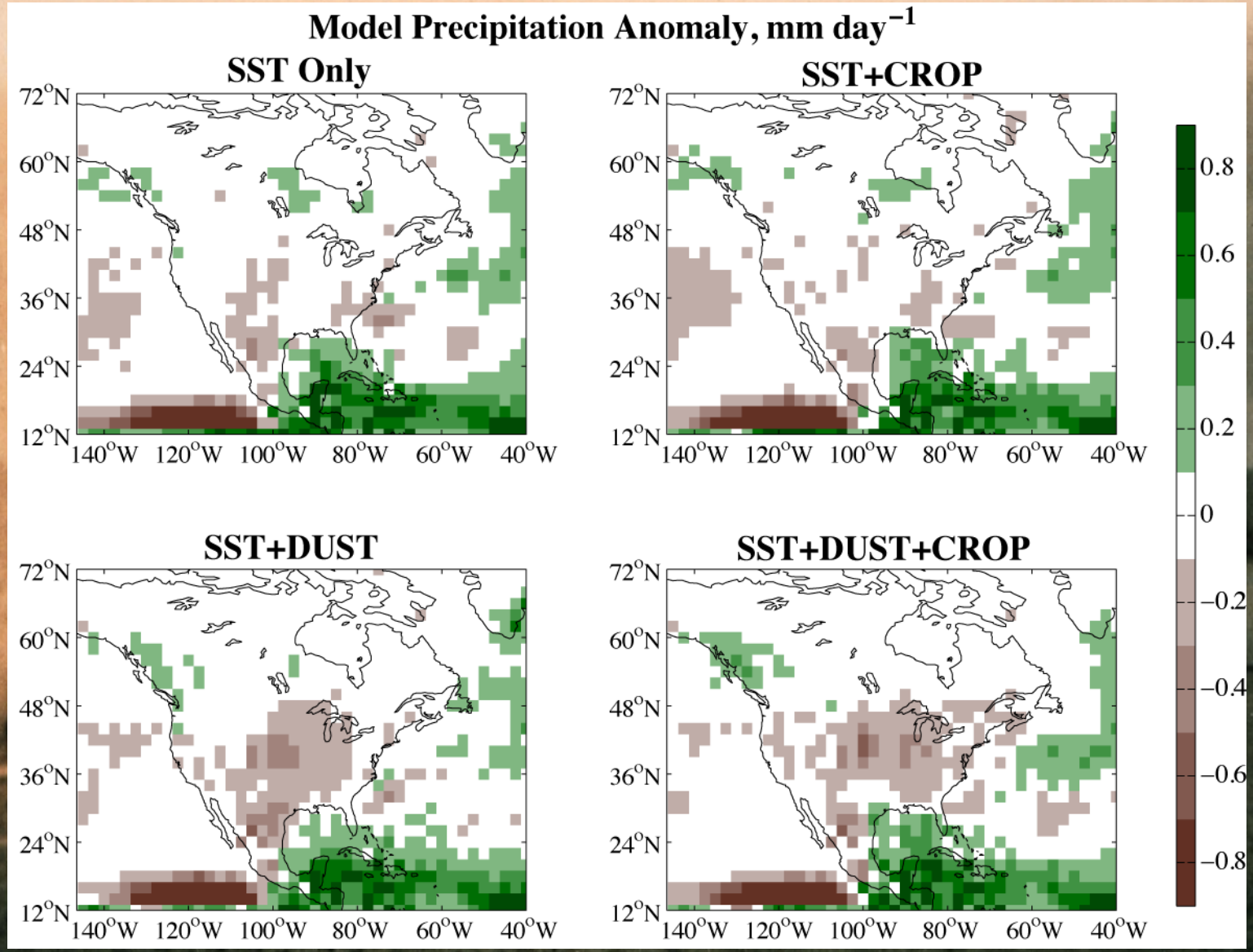
The 'Dust Bowl': Observed vs. Modeled



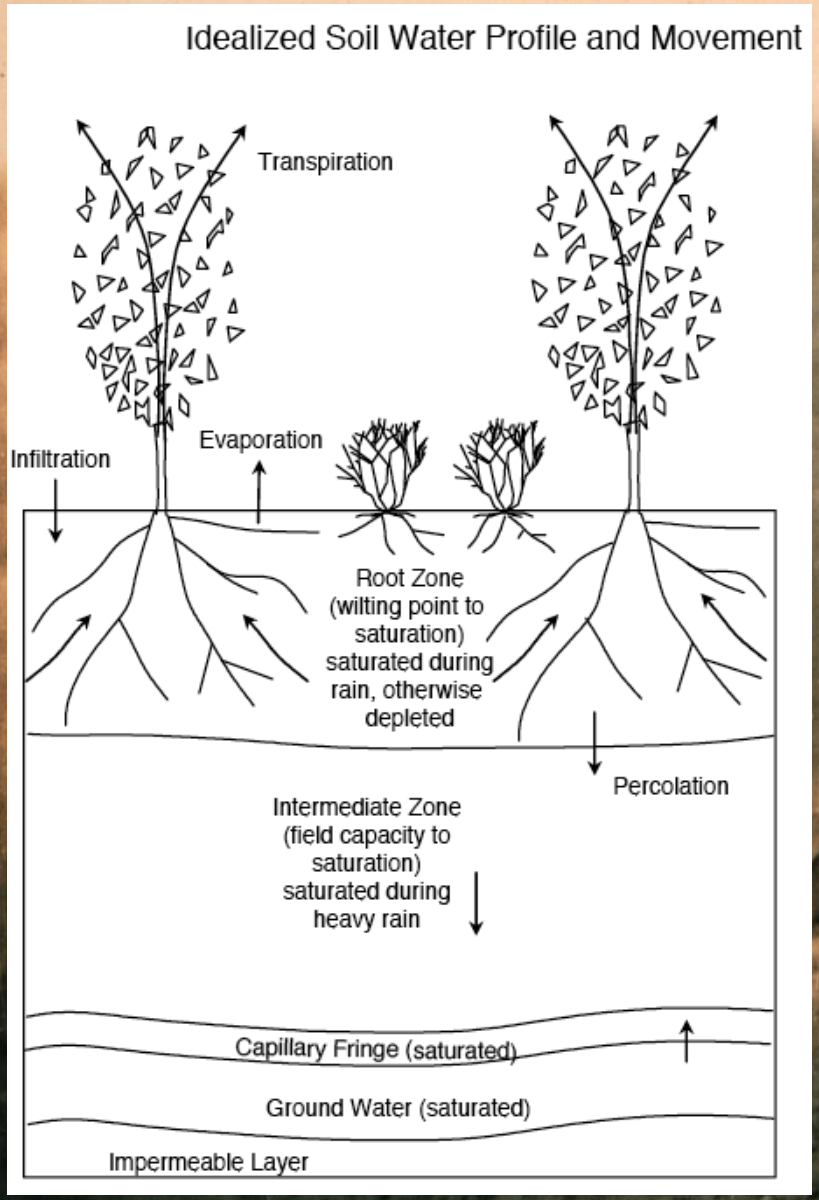
The 'Dust Bowl': Model Temperature

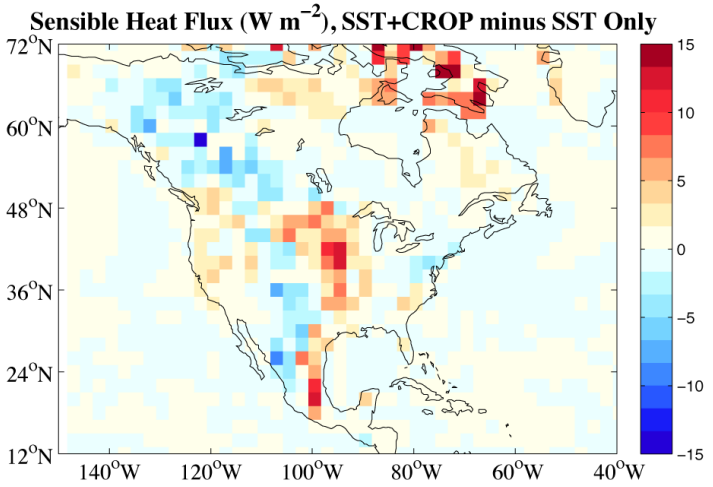


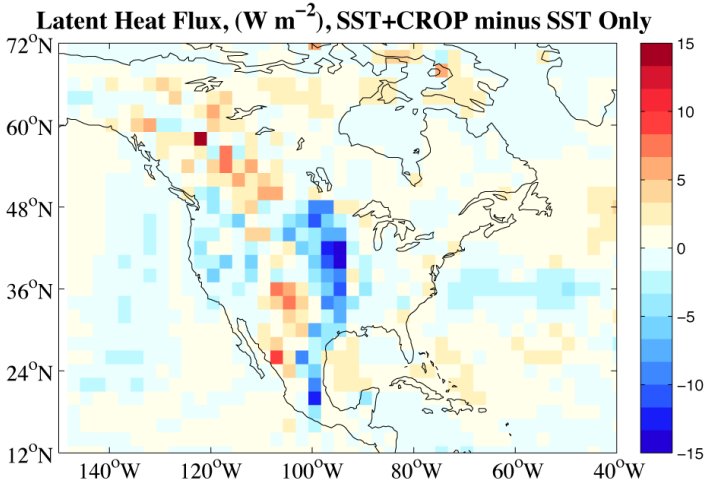
The 'Dust Bowl': Model Precipitation



Transpiration



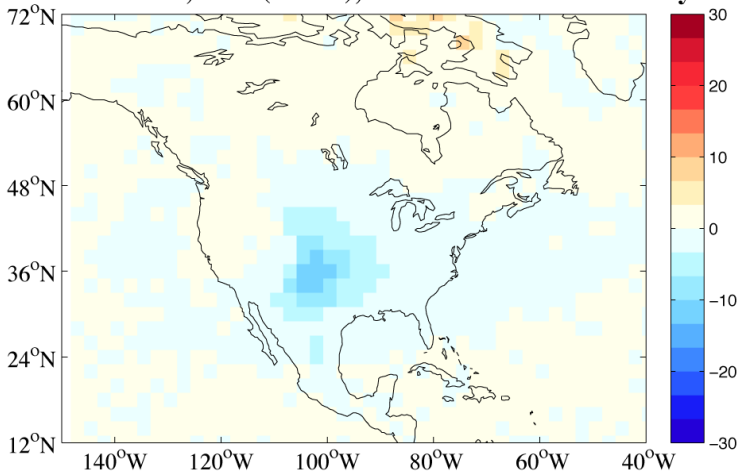




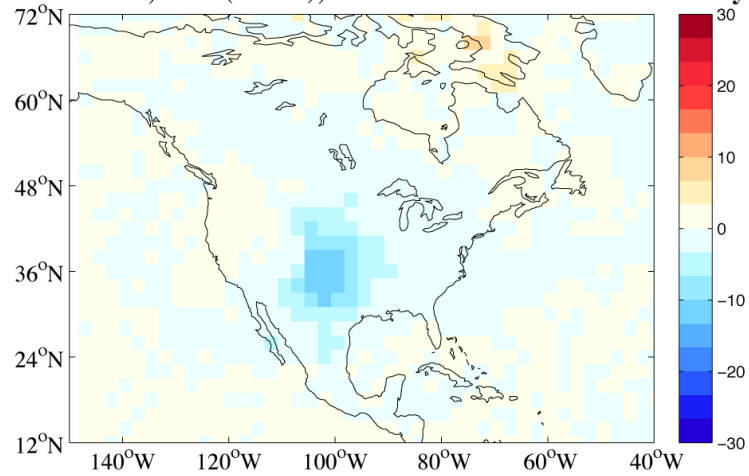
source: Bonan (2002), *Ecological Climatology*

Dust Forcing

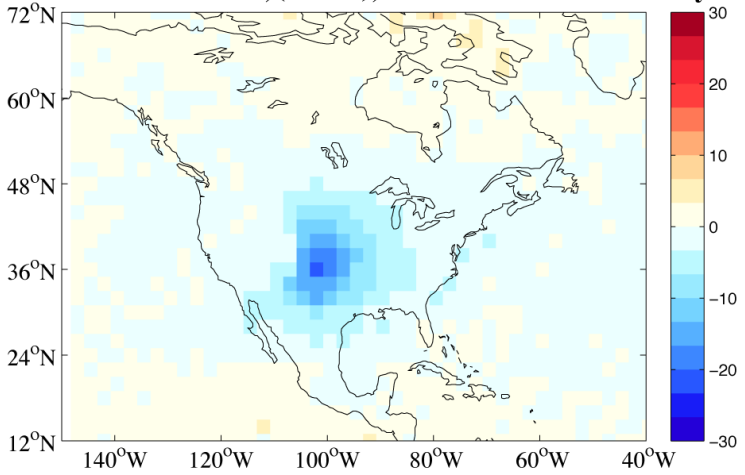
Net Radiation, TOA (W m^{-2}), SST+DUST minus SST Only



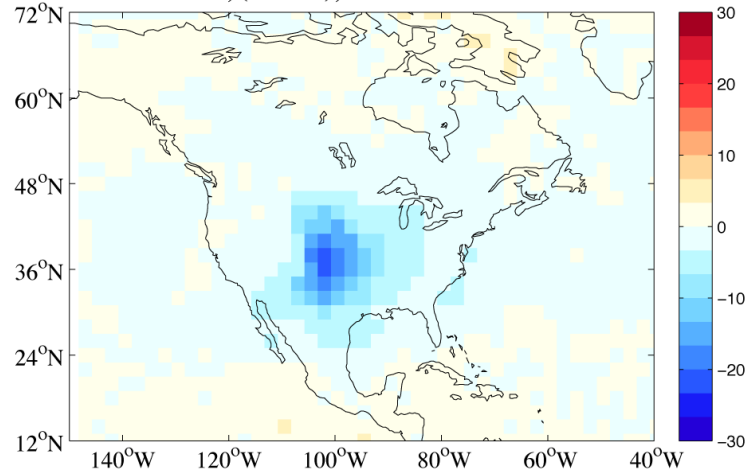
Net Radiation, TOA (W m^{-2}), SST+DUST+CROP minus SST Only



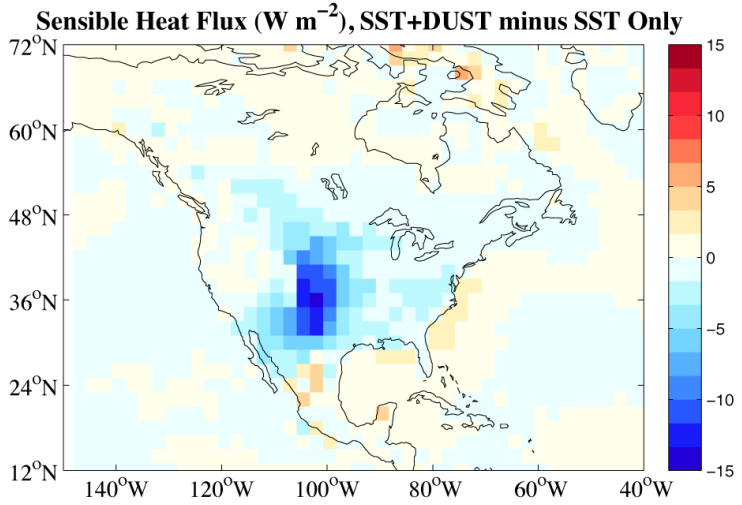
Net Surface Radiation, (W m^{-2}), SST+DUST minus SST Only

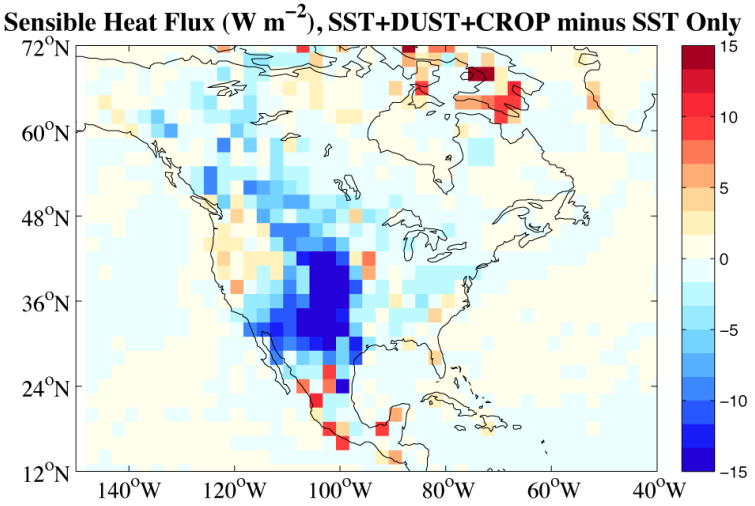


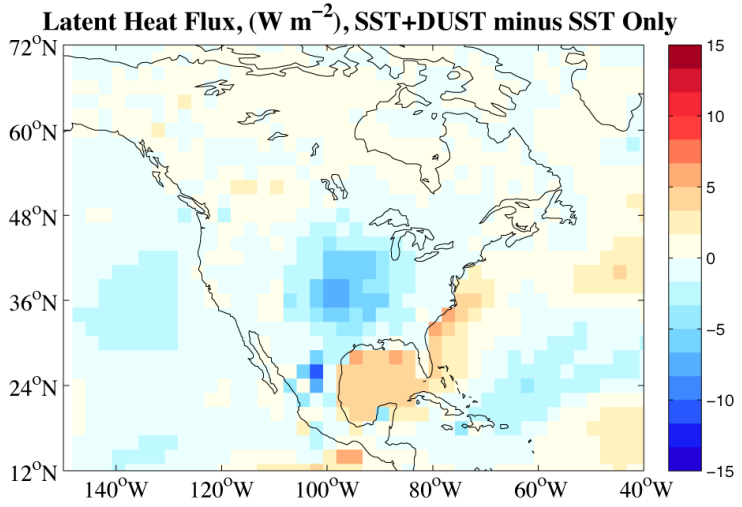
Net Surface Radiation, (W m^{-2}), SST+DUST+CROP minus SST Only

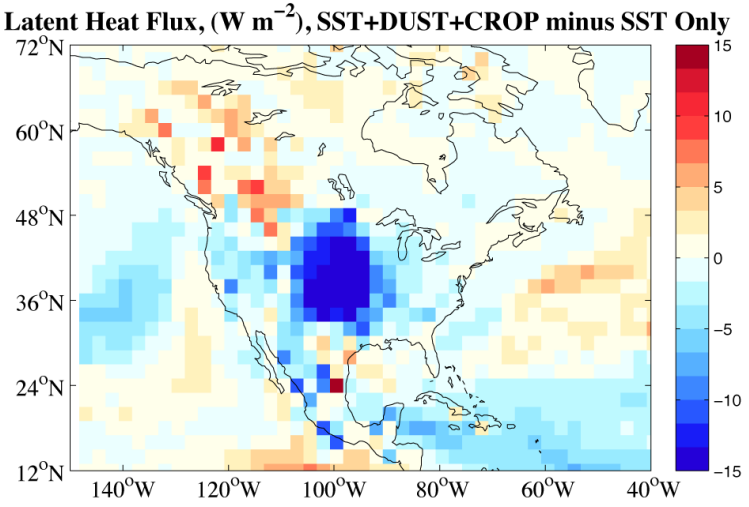


Dust Forcing: Bowen Ratio



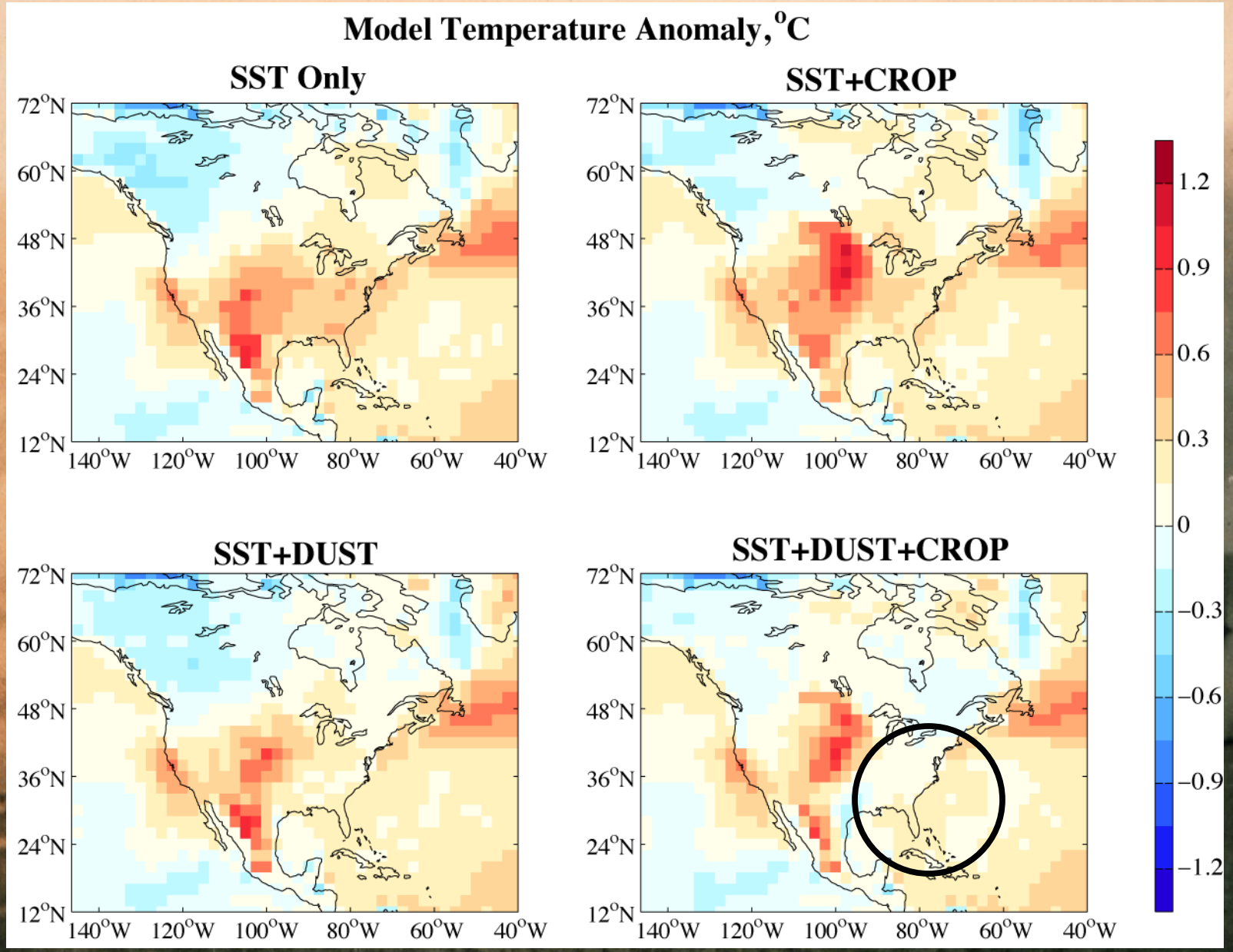


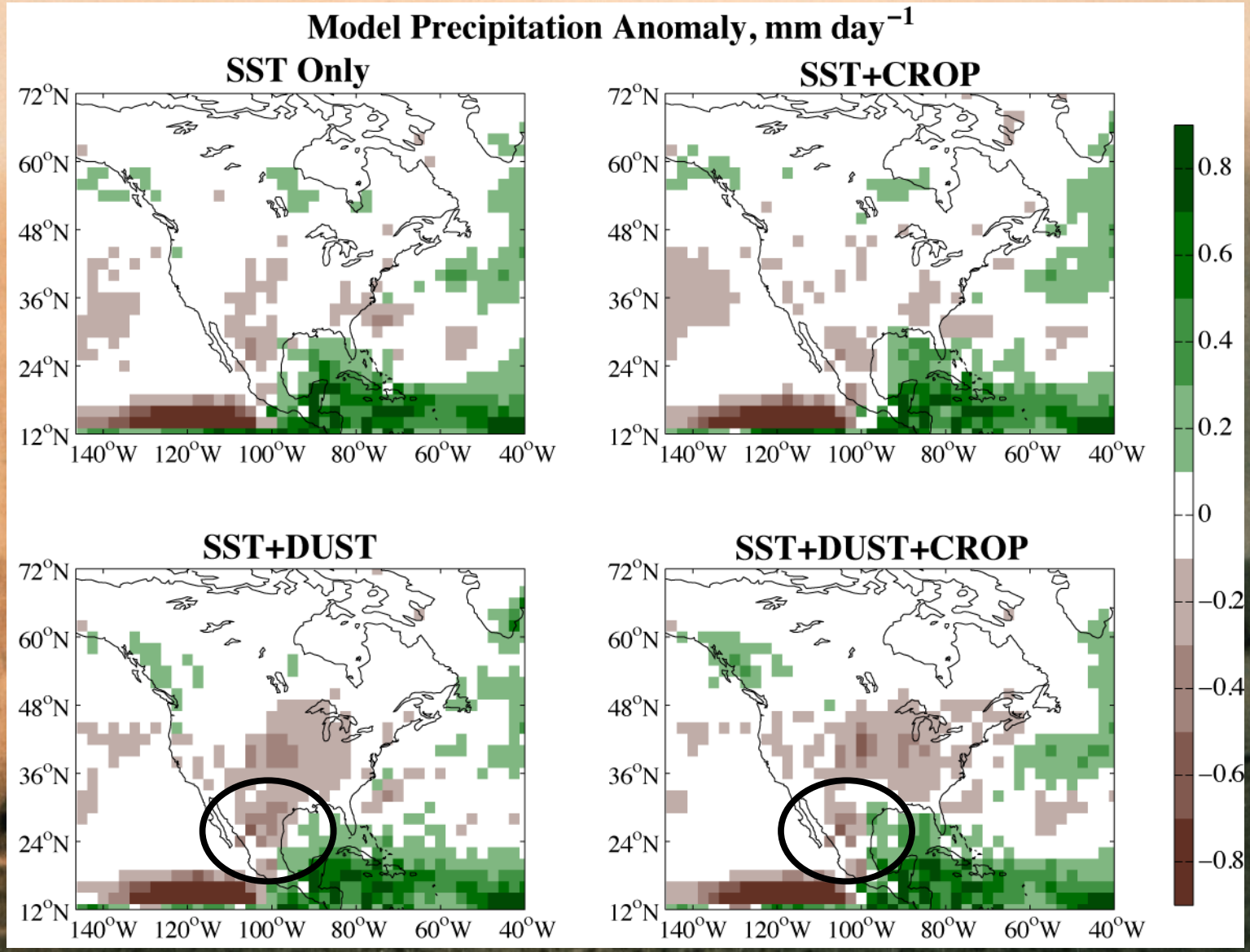




Surface Energy Balance

Simulation	LH Mean	SH Mean	LH+SH Mean	Bowen Ratio
SST-ONLY	107.34	55.47	162.81	0.517
SST+CROP	101.72	59.62	161.34	0.586
SST+DUST	98.79	50.04	148.83	0.507
SST+DUST+CROP	94.40	51.62	146.03	0.547
Differences Relative to Control				
SST+CROP	-5.63	4.15	-1.48	0.069
SST+DUST	-8.56	-5.42	-13.98	-0.010
SST+DUST+CROP	-12.94	-3.85	-16.79	0.030


Model Temperature Anomaly, °C
SST Only
SST+CROP
SST+DUST
SST+DUST+CROP
72°N
60°N
48°N
36°N
24°N
12°N
140°W
120°W
100°W
80°W
60°W
40°W
1.2
0.9
0.6
0.3
0
−0.3
−0.6
−0.9
−1.2


Model Precipitation Anomaly, mm day^{-1}
SST Only
SST+CROP
SST+DUST
SST+DUST+CROP
72°N
60°N
48°N
36°N
24°N
12°N
140°W
120°W
100°W
80°W
60°W
40°W
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8

Summary

- Improved simulation of the 'Dust Bowl' drought when land surface feedbacks are included
- Modeling uncertainties- are we simulating dust correctly? How would other models compare?
- Observational uncertainties-how much soil was eroded? How large an area was actually devegetated?

Thank You